



Faculty of Computer Science and Information Technology

**Centralized Intelligent Network Management for Energy Efficient
Resource Mechanism in Small Cell Network**

Abdul Qahar

**Doctor of Philosophy
2021**

Centralized Intelligent Network Management for Energy Efficient Resource Mechanism in Small Cell Network

Abdul Qahar

A thesis submitted

In fulfillment of the requirements for the degree of Doctor of Philosophy

(Wireless Network)

Faculty of Computer Science and Information Technology

UNIVERSITI MALAYSIA SARAWAK

2021

DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia, Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

.....

Signature

Name: Abdul Qahar

Matric No. 15010141

Faculty of Computer Science and Information Technology

Universiti Malaysia, Sarawak

Date:

DEDICATION

This thesis is dedicated to Allah Who

“(3) Created man, (4) [And] taught him eloquence”

(Holy Qur’an verses 3 and 4)

and

“(4) Who taught by the pen – (5) [and also] Taught man that which he knew not”

(Holy Qur’an 96 verses 4 and 5).

and

To the memory of my late parent

ACKNOWLEDGEMENT

In many instances during this doctoral dissertation journey, I have wondered when the day will come I will pay my gratitude to all the people responsible for putting this thesis forth. Today my words have fallen short to justify all the acknowledgments during this journey. Thanks be to Almighty Allah for providing me the strength to produce this research knowledge in the form of this doctoral thesis.

First, I am indebted to sincerely pay my gratitude and thanks to my supervisor and Dean, Associate Professor Dr. Kartinah Zen, for her marvellous and continuous guidance and encouragement throughout my Ph.D. It was Associate Professor Dr. Kartinah Zen's inexhaustible patience and support that enabled me to refine my Ph.D thesis and present it in this form at this crucial time. Associate Professor Dr. Kartinah has also been a moral support and a feeling of hope in the difficult times that I faced during this research process. I also would like to express my words of appreciation to my co-supervisor, Associate Professor Dr Johari Abdullah. I also want to say thanks to all the faculty members of the Faculty of Computer Science and Information Technology, UNIMAS. Special thanks to the Faculty of Computer Science and Information Technology for organizing research workshops and discussion valuable for Ph.D journey.

I would like to thank my brothers Mufti Muhammad Aqeel, Gulbar Khan, Molna Badruddin, Jawad khan, Eng. Awais, Abid and Eng. Fawad. my sisters, wife, children Muhammad Abdullah, Muhammad Ahmad, Ayesha, Amna and Muhammad Abdul Rahman, colleagues Ch. Iftikhar Ahmad, Dr Nusair, Dr Tehseen, Haji M.Ismaeel, Asif khan and friends Dr Ahmad Usman, Dr Qasim Nizamani, Prof. Raheel Akhtar, Dr Shiraz Ahmad and dear Bilal Ehsan. Lastly, I would give my sincere and true appreciation to my alma mater, University of the Punjab, Lahore, Pakistan which granted me the study leave.

ABSTRACT

Wireless Heterogeneous Small Cells Network (WHSCN) raised an enormous interest among communication industry and academia all around the world. Recent development of mobile services and applications has resulted in an imposing rise in the network traffic. In order to enhance the network capacity to meet the traffic demands, the Service Providers (SPs) make use of dense deployment of small cells base stations. However, dense deployment of small cells poses several challenges such as inefficient utilization of resources, imbalance of load during peak-hours and underutilization of resources during off-hours leading to high energy consumption and hence degrading the network efficiency of WHSCN. In order to address these issues, this research has proposed a centralized Intelligent Network Management (INM) mechanism. The INM mechanism is implemented in a centralized Small Base Station (SBS). This centralized SBS is known as High Signal Strength (HSS-SBS). The proposed INM mechanism has efficiently utilized the resources by monitoring the load of each SBSs in a cluster. INM also shares the SBSs' load by activating the centralized SBS during peak-hours and reducing high energy consumption by deactivating the under loaded SBSs during the off-hours. The simulation results show that the proposed mechanism outperforms in terms of decreased user rejection ratio only 3% during peak-hours while 30% reduced energy consumption as compared to Mobility Load Balancing (MLB) scheme of Random Sleep SBSs (RS-SBSs) and Sleep Only Centralized SBS (SOC-SBS) scheme during off-hours. Thus, the proposed INM mechanism has proved to be a better solution to address the issue of inefficient utilization of resources, imbalance of load sharing and energy inefficiency in the WHSCNs.

Keywords: Wireless small cell heterogeneous network, small base stations, service providers, intelligent network management, energy efficiency.

Mekanisme Pengurusan Sumber Tenaga yang Cekap untuk Rangkaian Sel Kecil

ABSTRAK

Rangkaian Sel Kecil Tanpa Wayar (WHSCN) menimbulkan minat yang besar di kalangan industri komunikasi dan ahli akademik di seluruh dunia. Perkembangan perkhidmatan mudah alih dan aplikasi baru-baru ini telah mengakibatkan kenaikan trafik rangkaian. Bagi meningkatkan keupayaan rangkaian untuk memenuhi permintaan trafik, Penyedia Perkhidmatan (SPs) memanfaatkan penempatan padat di stesen pangkalan sel kecil. Walau bagaimanapun, penggunaan padat sel-sel kecil menimbulkan beberapa cabaran seperti penggunaan sumber yang tidak cekap, ketidakseimbangan beban semasa waktu puncak dan penggunaan sumber yang tidak sepenuhnya (under utilization) semasa bukan waktu puncak sehingga menyebabkan penggunaan tenaga yang tinggi dan mengurangkan kecekapan rangkaian WHSCN. Untuk menangani isu-isu ini, penyelidikan ini telah mencadangkan mekanisme Pengurusan Rangkaian Pintar (INM) berpusat. Mekanisme INM dilaksanakan di Stesen Pangkalan Kecil (SBS) yang terpusat. SBS yang berpusat ini dikenali sebagai Kekuatan Isyarat Tinggi (HSS-SBS). Mekanisme INM yang dicadangkan telah menggunakan sumber dengan cekap dengan mengawasi beban setiap SBS dalam setiap kluster. INM juga berkongsi beban SBS dengan mengaktifkan SBS berpusat pada waktu puncak dan mengurangkan penggunaan tenaga yang tinggi dengan menyahaktifkan SBS semasa bukan waktu puncak. Hasil simulasi menunjukkan bahawa mekanisme yang dicadangkan adalah lebih baik dalam mengurangkan nisbah penolakan pengguna sebanyak 3% semasa waktu puncak dan mengurangkan penggunaan tenaga sebanyak 30% jika dibandingkan dengan Skim Imbuhan Beban Mobiliti (MLB) berdasarkan masa Tidur Rawak SBS dan Skim SBS Tidur Berpusat (SOC-SBS) semasa bukan waktu puncak. Oleh itu, mekanisme INM yang dicadangkan telah menjadi satu penyelesaian yang lebih baik

untuk menangani masalah penggunaan sumber yang tidak cekap, ketidakseimbangan perkongsian beban dan ketidakcekapan tenaga dalam WHSCN.

Kata kunci: *Rangkaian sel kecil pelbagai tanpa wayar, stesen pangkalan kecil, penyedia perkhidmatan, pengurusan rangkaian pintar, kecekapan tenaga*

TABLE OF CONTENTS

	Page
DECLARATION	i
DEDICATION	i
ACKNOWLEDGEMENT	iii
ABSTRACT	iv
<i>ABSTRAK</i>	v
TABLE OF CONTENTS	vii
LIST OF TABLES	xii
LIST OF FIGURES	xiii
LIST OF ABBREVIATIONS	xvi
CHAPTER 1: INTRODUCTION	1
1.1 Background of the Study	1
1.2 Problem Statement	4
1.3 Research Questions	5
1.4 Research Objectives	6
1.5 Research Scope	6
1.6 Significance of the Research	7
1.7 Thesis Structure	7
1.8 Summary	8
CHAPTER 2: LITERATURE REVIEW	10
2.1 Introduction	10

2.2	Evolution of Cellular Networks	11
2.3	Existing Load Balancing and Energy Efficient Solutions for Small Cell Networks (SCNs)	14
2.3.1	Mobility Load Balancing Method for Self-Organizing Wireless Networks	15
2.3.2	Improving Load Balancing in various User Distributions LTE-Advance HetNets	17
2.3.3	Load Balancing Models based on Reinforcement Learning	19
2.3.4	Joint Dynamic Radio Resource Allocation and Mobility Load Balancing	21
2.3.5	Multi-Criteria Load Balancing Decision Algorithm	22
2.4	Existing Handover Mechanism in Cellular Network	25
2.4.1	Handover management in LTE-based multi-tier femtocell networks	26
2.4.2	Context-Aware Handover Policies in HetNets	27
2.5	Existing Energy Efficiency Solutions for Heterogeneous Small Cell Networks (HSCNs)	28
2.5.1	A Load-Balancing Energy Consumption Minimization Scheme in 5G Heterogeneous Small Cell Networks	29
2.5.2	An Energy-Efficient Solution for Cellular Network	32
2.5.3	Energy Saving in Heterogeneous Networks with Clustered Small Cell Deployments	33
2.5.4	Green Communication System for Reducing Energy Consumption in Cellular Networks	35
2.5.5	A Novel Sleep Mode Control Algorithm for Reducing Energy Consumption of 5G Ultra Dense SCN	37

2.5.6	A network Graph Approach for Energy Saving in Small Cell Networks	38
2.5.7	Base Stations Switch off Algorithm in Multi-Operator Shared HetNet for Energy Saving	39
2.6	Overview of Simulation Tools	44
2.7	Summary	46
CHAPTER 3: METHODOLOGY OF DESIGNING AN INTELLIGENT NETWORK MANAGEMENT MECHANISM AND SCHEMES		47
3.1	Introduction	47
3.2	Intelligent Network Management Mechanism	48
3.2.1	Load Monitoring and Sharing	50
3.2.2	Intelligent Activation of High Signal Strength SBS Scheme	55
3.2.3	Intelligent Activation and De-Activation of SBSs (IAD-SBSs) Scheme	57
3.3	System Model	60
3.4	Network Model	62
3.5	Evaluation Metrics	64
3.5.1	Energy Consumption	64
3.5.2	User Rejection Ratio	65
3.6	Analysis of Existing Heterogeneous Small Cell Network Solutions	65
3.7	Summary	72
CHAPTER 4: DESIGN OF LOAD MONITORING AND SHARING SCHEME		73
4.1	Introduction	73
4.2	Load Monitoring and Sharing (LMS) Scheme	74
4.2.1	Centralized Load Monitoring	75

4.2.2	Centralized Load sharing	79
4.3	Results Analysis and Discussion of Centralized Load Monitoring and Sharing Scheme	84
4.3.1	Energy Consumption	92
4.3.2	Users Rejection Ratio	93
4.4	Summary	96
CHAPTER 5: DESIGNING OF INTELLIGENT ACTIVATION OF HIGH SIGNAL STRENGTH SMALL BASE STATION SCHEME		97
5.1	Introduction	97
5.2	Intelligent Activation of High Signal Strength SBS Scheme	98
5.3	Results Analysis and Discussion of Centralized Load Monitoring and Sharing Scheme	104
5.3.1	Energy Consumption	108
5.3.2	Users' Rejection Ratio	109
5.4	Summary	111
CHAPTER 6: DESIGN OF INTELLIGENT ACTIVATION AND DE-ACTIVATION OF SBS_s SCHEME		112
6.1	Introduction	112
6.2	Intelligent Activation and De-Activation of Underutilized SBS Scheme	113
6.3	Results Analysis and Discussion of Intelligent Activation and De-Activation of SBSs Scheme	117
6.3.1	Energy Consumption	124
6.3.2	User Rejection Ratio	132

6.4	Summary	134
CHAPTER 7: CONCLUSION AND RECOMMENDATION FOR FUTURE WORK		136
7.1	Implication of the Research	136
7.2	Contributions	137
7.3	Future Work	138
7.4	Summary	139
REFERENCES		140

LIST OF TABLES

	Page
Table 2.1 Comparison of Different Generations	14
Table 2.2 Detail of the SBS Hardware Components Power Consumption	31
Table 2.3 Related work	40
Table 3.1 RSI Table Load Detail of cluster-1 SBSs during off peak-hours	50
Table 3.2 Load Status of Small Base Stations.	55
Table 3.3 Simulation Parameters and Notations	63
Table 4.1 SBSs users' load of seven cells cluster	89
Table 4.2 After 30 seconds SBSs' users' load detail of seven cells cluster	89
Table 4.3 Detection of rapid load increase of an SBS	90
Table 4.4 The calculation of rapid load increase in SBS of cluster-1	90
Table 4.5 The load status of SBS-3, SBS-4 and SBS-5 after sharing	91
Table 5.1 Before Activation of Centralized SBS	105
Table 5.2 After Activation of HSS-SBS	105
Table 5.3 After Activation of HSS-SBS	106
Table 5.4 After Activation of HSS-SBS	107
Table 6.1 After 30 seconds SBSs users' load details of seven cells cluster-1	119
Table 6.2 Detection of rapid load decrease of SBS	119
Table 6.3 The calculation of the rapidly load decrease in SBS of cluster-1	120
Table 6.4 After handing over the load to rapidly load decreasing SBS-5	120
Table 6.5 After handing over the load of SBS-7 to HSS-SBS	121
Table 6.6 Load details of all SBSs of cluster-1 after turning SBS-5 to sleep mode	122

LIST OF FIGURES

	Page
Figure 1.1 Imbalance of load among Base Stations and underutilization of SBSs during off peak-hours	3
Figure 2.1 A cellular network scenario (The shadow part represents sleeping BS)	33
Figure 2.2 System architecture of a heterogeneous network where UEs support dual connectivity	34
Figure 2.3 Outline of the energy-efficient system from	37
Figure 3.1 Flow of the Proposed Contributions	49
Figure 3.2 Handover Procedure in LTE System	51
Figure 3.3 INM Load Monitoring and updates of CUs and FCs list	53
Figure 3.4 Load Sharing among SBSs	54
Figure 3.5 Flow Chart of the IAHSS-SBS Scheme	56
Figure 3.6 Flow Chart of IAD-SBSs Scheme during off peak-hours	58
Figure 3.7 Flow Chart of INM Mechanism	60
Figure 3.8 System Model of INM	62
Figure 3.9 Part of Lahore city map considered for INM mechanism evaluation	63
Figure 3.10 Existing Load Balancing scheme when SBS Load reaches 90% load	637
Figure 3.11 A Flow Chart of Existing Scheme	639
Figure 4.1 INM Load Monitoring and updates of CUs and FCs list	76
Figure 4.2 SBSs load detail of the cluster-1	78
Figure 4.3 SBSs load detail of the cluster-1 after 30 seconds	79
Figure 4.4 Flow chart of the LMS Scheme	80
Figure 4.5 Detail of users in a cell and cell parts	81

Figure 4.6	Detail of Cell Area	82
Figure 4.7	cluster-1 SBSs load after load sharing	83
Figure 4.8	First Phase (a) Users 20%	85
Figure 4.9	First Phase (b) Users 40%	85
Figure 4.10	First Phase (c) Users 60%	86
Figure 4.11	First Phase (d) Users 70%	86
Figure 4.12	First Phase (e) Users 80%	87
Figure 4.13	First Phase (f) Users 85%	87
Figure 4.14	First Phase (g) Users 90 %	88
Figure 4.15	Traffic Load vs Energy Consumption	92
Figure 4.16	Traffic Load vs Users Rejection	94
Figure 4.17	Traffic Load vs Users Rejection	94
Figure 4.18	Traffic Load vs Users Rejection	95
Figure 4.19	Traffic Load vs Users Rejection	95
Figure 5.1	Load status of cluster-1 SBSs before activation of Centralized SBS	99
Figure 5.2	Activation of HSS-SBS and Allocation of connections from HSS-SBS to Users	100
Figure 5.3	Load status of cluster-1 after Activation of HSS-SBS	101
Figure 5.4	Load status of cluster-1 after few minutes of Activation of HSS-SBS	102
Figure 5.5	Load status of cluster-1 after few minutes of Activation of HSS-SBS	103
Figure 5.6	Load status of cluster-1 during peak-hours	104
Figure 5.7	Increases Traffic Load vs Energy Consumption	109
Figure 5.8	Increases Traffic Load Vs Users Rejection	110

Figure 6.1	Detection of SBS rapid load decreasing and Load sharing during off peak-hours	116
Figure 6.2	The traffic load details of cluster-1 before the execution of LS and AD-SBSs algorithm.	118
Figure 6.3	After SBS-5 load is handed over to HSS-SBS	122
Figure 6.4	Load of five SBSs 50 % users only	123
Figure 6.5	Load of five SBSs 40 % users only	123
Figure 6.6	Only HSS-SBS active during off peak-hours	124
Figure 6.7	Traffic Load VS Energy Consumption during off peak-hours of SCN	126
Figure 6.8	Traffic Load VS Energy Consumption during off peak-hours of SCN	127
Figure 6.9	Traffic Load VS Energy Consumption during off peak-hours of SCN	128
Figure 6.10	Traffic Load VS Energy Consumption during off peak-hours of SCN	129
Figure 6.11	Traffic Load VS Energy Consumption during off peak-hours of SCN	130
Figure 6.12	Traffic Load VS Energy Consumption during off peak-hours of SCN	131
Figure 6.13	Traffic Load VS Energy Consumption during off peak-hours of SCN	132
Figure 6.14	Traffic Load VS Users Rejection Ratio	133
Figure 6.15	Traffic Load VS Users Rejection Ratio	133

LIST OF ABBREVIATIONS

1G	1 st Generation
2G	2nd Generations
3G	3rd Generations
3GPP	3rd Generation Partnership Project
4G	4th Generations
4 G-LTE	4th-Generation-Long-Term Evolutions
5G	5th Generations
ADNSF	Access Network Discovery and Selection Function
AF	Amplify-and-forward
ANDSF	Access Network Discovery and Selection Function
BS	Base Station
CA	Carrier Aggregation
CL	Current Load
CDMA	Code Division Multiple Access Technique
COFDM	Coded Orthogonal Frequency Division Multiplexing
CN	Core Network
CRAN	Cloud RAN
CSI	Channel State Information
D2D	Device-to-Device
DB	Database
DBS	Database System
DF	Decode-and-forward
DL	Downlink

DSL	Digital Subscriber Line
DRAN	Distributed RAN
EARTH	Energy Aware Radio Technologies
EE	Energy Efficiency
ENodeB	Evolved Node B
ERULB	Efficient Resource Utilization and Load Balancing
FDMA	Frequency Division Multiple Access
Gb	Gigabits
GoS	Grade of Service
GR	Green Radio
GSM	Global System for Mobile
GSM	Global System for Mobile
GUIDE	Graphical User Interface Development Environment
HCGAA	Hybrid Channel Gain Access Aware
HDTV	High Definition Television
HetNets	Heterogeneous Networks
HEW	High Efficiency WLANs
HSR	High Signal Range
HSS	High Signal Strength
HPNs	High power nodes
ICI	Inter-cell interference
INM	Intelligent Network Manager
INMC	Intelligent Network Manager Layer Controller
INML	Intelligent Network Manager Layer

InPs	Infrastructure Providers
IMT-Adv	International Mobile Telecommunications-Advanced
IOT	Internet of Things
ITU	International Telecommunications Union
KJ	Kilo Joule
LB	Load Balancing or Balancer
LBRL-T	Reinforcement Learning of Macro Cell-Throughput
LC	Load Controller
LD	Load Dividing or Divider
LPNs	Low power nodes
LSR	Low Signal Range
LTE	Long Term Evolution
MBS	Macro cell Base station
MCF	Multi-Criteria Function
MeNB	Macro Evolved Node B
MIMO	Multiple Input Multiple Outputs
MB	Mega Byte
MLB	Mobility Load Balancing
MM-Wave	Millimeter Wave
Multi-RS	Multi-Relay Station
MVCE	Mobile Virtual Centre of Excellence
MVNOs	Mobile Virtual Network Operators
NTR	Non-Transparent Relay
NVS	Network Virtualization Substrate

OPEX	Operational expenditure
PeNB	Pico Evolved Node B
PL	Previous Load
PNC	Physical Network Controller
PNRL	Physical Network Resource Layer
PNRLC	Physical Network Resource Layer Controller
PR	Physical Resource
PRB	Physical Resource Blocks
RACH	Random Access Channel
RL	Reinforcement Learning
RBS	Relay Base Station
RSRP	Reference Symbols Received Power
RSRQ	Reference symbols received quality
QL	Q-Learning
QoS	Quality of Service
RACH	Random Access Channel
RAN	Radio Access Network
RANaaS	Radio-Access-Network-as-a-Service
RAT	Radio Access Technologies
RBS	Relay cell Base station
RBs	Resource Blocks
RRM	Radio Resource Management
RS	Reference Signal
RS-SBSs	Random Sleep Small Base Stations

RRA	Radio Resource Allocation
RSI	Resource State Information
RSRP+CRE	Reference Signal Receive Power plus Cell Range
SBS	Small cell Base station
SCNs	Small Cell Networks
SCs	Small Cells
SINR	Signal to Interference-plus-Noise Ratio
SNR	Signal to Noise-Ratio
SOC-SBS	Sleep Only Central Small Base Station
SON	Self-Organizing Network
SPs	Service Providers
UDNs	Ultra-Dense Networks
UE	User Equipment
UL	Uplink
VBs	Virtual Base Stations
WANs	Wireless Access Networks
WHN	Wireless Heterogeneous Network
WiFi	Wireless Fidelity
WLAN	Wireless Local Area Network
WSCNs	Wireless Small Cell Networks
WVN	Wireless Virtualized Network

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

In order to meet the demand of wireless networks coverage capacity a design paradigm called the Heterogeneous Network (HetNet) was introduced in Long Term Evaluation (LTE) (Li et al., 2015; Marsan et al., 2013). The idea of HetNet is to deploy several small cells under the coverage of macro cells to extend coverage and to boost capacity in certain high-demand urban areas (Li et al., 2015). HetNet represents a major paradigm shift in cellular network designs and offers enhancement in network and coverage. The HetNet introduced small cell and the network of small cells is called Small Cell Network (SCN). The small cells have short range coverage area, low cost and low power cellular base station designed for small business environment (Tao et al., 2019; Dahlman, et al., 2014). According to Ming-Chin et al. (2015), the purpose of small cells is to enhance communication quality when the user is located in a weak signal area such as the boundary of a base station coverage and basement of a building. Moreover, small cells also share the macro cell load in wireless network.

A small cell is a cellular coverage area, which is served by a low-power Small Base Station (SBS) (Qutut, 2014). SBS is a fully featured Base Station (BS) that is typically intended to be user-deployed for indoor deployment such as offices, residential homes, shopping malls, railway stations, airports, subways, highways and backhaul to the operator's Core Network (CN) via internet connection such as Digital Subscriber Line (DSL) and cable (Qutut, 2014; Inform and small cell Forum, 2013). There are different types of small cells like femto, pico, micro and macro. The femto cell is the shortest coverage area. Therefore, it is the smallest type of small cell. The range of femto cell is up

to 100 meters. It is used for indoors like offices and homes. The Pico is the second smallest type of small cell which covers maximum of 200 meters. It is also used for indoors like homes and offices. The micro cell coverage area is up to 1000 meters i.e. 1 km. The use of the micro cell is high due to its high coverage capacity as compared to femto and Pico which are mostly deployed at the public places such as shopping malls and railway stations. The biggest type of small cell is called macro cell and its coverage is 3 to 5 km in diameter that can be enhanced and mostly deployed at the universities, airports and highways (Electronic design, 2018; Mobile network guide, 2018; Bernard, 2014).

Normally in the urban areas the number of users increase during daytime working hours. In literature, the increase of users increases the users' load on a network. While the period of users' high load is called peak-hours. In addition, a base station reaching 90% of its load capacity is known as loaded state. So, when the users' load is high during peak-hours the small cell base stations of urban area reach the loaded state. Consequently, the users of urban area will be facing the problem in accessing the network for availing the services. In this scenario where the number of users increases rapidly during peak-hours, the dense deployment of SBSs is a prerequisite by operators to extend the network coverage and to facilitate the maximum users (Musleh et al., 2017; Wang et al., 2016). Therefore, operators deploy more SBSs to serve more users and enhance the network coverage. Normally the operators increase the number of SBSs to handle the peak-hours load.

However, these dense deployments of SBSs are not efficiently utilized during normal and off-hours. Thus, some SBSs are serving many users whereas some are serving only a few ones in the SCN of urban areas. In literature, this issue is called inefficient utilization of resource and imbalance of load among SBS. Therefore, the extension of